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Design of an
Interurban Car for high Speed Service

Railway Electrical Engineering

B. S.

1914

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DESIGN OF AN INTERURBAN CAR FOR HIGH SPEED SERVICE

BY

BENITO RENÉ ORDÓÑEZ
B. S. UNIVERSITY OF ILLINOIS, 1913

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

RAILWAY ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

BENITO RENÉ ORDÓÑEZ, B.S.

ENTITLED THE DESIGN OF AN INTERURBAN CAR FOR HIGH SPEED SERVICE.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF BACHELOR OF SCIENCE
in
RAILWAY ELECTRICAL ENGINEERING

A M Buck
Instructor in Charge

APPROVED: Edward C. Schmidt

HEAD OF DEPARTMENT OF Railway Engineering

284620

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I INTRODUCTION

The subject of this thesis is the design of a high speed passenger car for interurban service. The design is intended to appeal to such roads as give a limited service over comparatively long distances; and the arrangement is such as to appeal to the traveling public, who desire both rapid service and ordinary comforts during the journey. It has also been designed so as to keep the weight per seated passenger a minimum, and to reduce the power consumption so far as consistent with good design and strength.

The power for the car has been so proportioned that high speed can be obtained with reasonably high accelerations, 1.6 miles per hour per second being obtainable when using the car singly and about .9 miles per hour per second when a fully loaded trailer of the same construction, weighing about 40 tons is used; the loaded motor car weighing 50 tons. When two such trailers are used the acceleration will probably decrease to .63 miles per hour per second. The maximum speed in the three cases will be about 60,50 and 40 miles per hour respectively.

The all-steel design has been chosen since quality and durability are the most desirable features. In order to obtain the most rigid framing for the least weight of material, pressed steel shapes are used whenever found practicable.

The high speeds intended for the car, were taken in consideration in the design of the end forms. The parabolic front and circular rear end were found to give the most suitable com-

bination to minimize air resistance. The energy thus saved is from 20 to 30 percent, according to Crosby's experiments.*

This item of end shapes, seems to be almost completely disregarded by many car builders of to-day, perhaps because it interests the purchaser more than it does the builders from the economical point of view.

By the use of the center entrance, the passenger and smoking compartments have direct and short exit;both compartments being absolutely independent of the baggage compartment and motorman's cab, a very desirable feature. On the other hand, by using center entrance, only one vestibule is necessary, thus using more efficiently the floor space of the car and diminishing the weight per seat very considerably. The seating capacity of the car being 72 and its estimated weight 85,600 lb. the weight per seat is reduced to 1190 lb . In general the weight of interurban cars is about 1400 lb. per seat when arranged for over 60 passengers such as this one is. According to these figures, a saving of 15 percent from the average weight per seat has been obtained, and if compared with steam road practice the saving is from 30 to 40 percent based on passenger car weights.

The car has been equipped with multiple unit control for the possibility of using this type of car in long motor-car trains. The trolley potential being 1200 volts, the two motors of each truck must operate in series although they are insulated for 1200 volts. A dynamotor pump is to furnish the 600 volt potential for the operation of the rest of the electrical equipment in general. A storage battery is to be kept continually charged so

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* Foster's Electrical Engineers Pocket Book.

that in case of no potential on the trolley, the side lights may be kept lit for considerable time.

Every dangerous piece of apparatus is intended to be of such construction and installation, that would guarantee safety to the operator.

Quality and economy have been considered in every detail.

II SPECIFICATIONS FOR THE DESIGN OF RAPID SERVICE ALL-STEEL INTERURBAN CAR

1. General Dimensions

Length over buffers	65'
Length of body proper	63'-7 3/4"
Length of vestibule	32"
Width maximum	9'-6"
Height from bottom sill to top of ventilators	9'-9 1/2"
Height from top of rail to top of ventilator	13'-4"
Height from floor to underside of ceiling	8'-6"
Height from floor to window rest	30 1/2"
Height from rail to underside of body bolster	42 1/2"
Height from rail to first step	15"
Height from top of rail to center line of couplers	34 1/2"
Center to center of side posts	5'-3"
Truck centers	42'-6"
Wheel base	7'-0"

2. Inspection

Purchaser's representative will come to builders works when the latter is ready to start drawings. All drawings, designs, details and construction are to be approved by him and he shall be at liberty to inspect workmanship and material at any time and shall have the right to reject all material and workmanship which are not in his opinion up to the standard set by these specifications. No material is to be put into this car until approved

by this inspector.

3. Material

All materials entering into the construction of these cars, must be first class in every respect, and able to stand ordinary commercial tests. All iron and steel must be of standard quality and all bolts, rods, rivets and screws must be free from defects. All other materials such as malleable iron, bronze, copper, steel castings, painting materials, glass, etc., must be first class.

4. Workmanship

All rivets must be put in hot and all joints to be tight whether covered or not. Rivets showing on the outside, to be made with round heads 1/4" high. Where metal is placed against metal, both are to be coated with peroxide of iron paint. All hidden work is to receive a coat of paint.

Special care must be taken with the inside finish, to have all joints perfect and arranged so that they can be taken down should occasion require.

5. Body Proper

A. Bottom frame

Center sills to be made of 8" 16.25# channels* to extend the entire length of the car. They must consist of single pieces only joined at the end to the curved side-sill as shown on frame drawings.

Side sills are to be made of 8"- 11.25# channels in five

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* All structural steel shapes used in this design are Cambria standard and all sheet metal is specified in United States Standard gauge .

sections each as shown on drawings, both ends to be riveted with butt joints with 7" Hedley anti-climbers.

The anti-climbers are 6'-6" long at the front end and 6' at rear end.

The end plates must be #1 rolled steel and must be riveted to side and center sills. Main bolsters to be made of two rows of pressed steel shapes of #3 steel, between sills, riveted to them and to #000 plates above and below. A 13"-32# special channel is bent, reinforced and riveted to the under plate to support the truck bearing plate, as shown on cross-section A.

Bolsters are to be made of a single row of pressed steel shapes between sills, riveted to them and to #1 steel plates above and below.

The drawbars shall be M. C. B. standard for the possibility of handling one or more trailer cars.

B. Floors

The floors are to be constructed of a #8 steel plate bolted to sills and bolsters covering the whole floor space, a 3/8" sheet of Agasote or other non-combustible material is bolted to the plate and a 1/4" surfacer is laid over it.

C. Sides

The sides are designed reasonably heavy so that they will act as plate girders and transmit the load from car to trucks thru main bolsters.

Pressed steel shapes are used thruout, being designed to have minimum weight for maximum stiffness. The lower member of the gird-

ers is the side sill channel and the upper, a continuous 4" x 4"-8.2# angle.

Window posts and letter board are all included in the side shapes.

The side sheathing to be made of carefully fitted #12 plates riveted to side framing.

D. Bulkheads

Bulkheads are to be built of steel framing and sheathing of as light construction as is consistent with necessary strength. Finish, to be the same as the rest of the interior.

E. Roof

The roof.to be of plain arch type made of a #14 plate riveted to the carlines. 1/4" Agosote is riveted to this plate and finally covered with #8 canvas, filled with three coats of first quality lead filler and painted.

F. Windows

Windows are to have pressed steel sashes 3/4" thick as shown on drawings and glazed with AA-DS glass.

G. Doors

Doors are to have pressed steel frames and glass,when used, to be AA-DS.

6. Vestibule.

The vestibule of this center entrance car consists of two bulkheads with their respective doors to passenger and smoking compartments. No glasses are used on the bulkheads. Doors to be glazed as

shown in cross sections C and D.

Trap doors are used to cover the steps, each trap door to operate simultaneously with its respective four-leaf door and sliding step by pneumatic power controlled by a valve in the vestibule.

The entrance doors to be built of pressed steel shapes and A. A. - D. S. glass used for glazing.

A water tank forms the ceiling of the vestibule and is so supported that it can be taken out easily.

Steps to be pressed steel shapes #8 plates. Sliding step to be built of pressed steel shapes #14. plates.

7. Interior

A. Finish

Headlinings to be of #14 steel riveted to car lines with countersunk rivets.

Trimmings to be selected by purchaser's representative.

The rest of the interior lining to be of #14 sheet steel perfectly adjusted and free from defects.

B. Seats

Seats are to be Ford & Johnson Co's. high back reversible, plush finish in dark green, or other seats of equal quality acceptable to purchaser's representative.

C. Curtains

Curtains of all side windows to be made of dark green Pantasote hung by Hartshorn spring rollers, and equipped with Curtain Supply Co's. #88 ring fixture, or other fixtures of equal

quality.

D. Signal bell.

The signal bell is to be operated by the storage battery automatically when door is opening and closing.

An electrically operated inter-locking device, prevents operating the controller when any one of the side doors is open.

E. Electric lighting.

The dynamotor will furnish direct current at 600 volts to be used for lighting.

All lamps used in the car to be drawn wire tungsten type, arranged to operate 5 in. series on 600 volts.

a. Passenger compartment

Three clusters of 5-25 watt lamps placed in series; all clusters to be connected in parallel. The five side lights on each side are connected in series and the two sides in parallel; 20 watt lamps to be used.

b. Smoking compartment

Two clusters of the type used in the passenger compartment to be installed as shown on drawings.

c. Toilet rooms

The toilet room lights consist of one 20 watt lamp each; in the forward compartment, in series with the four 20 watt side lights of the smoking compartment and in the rear compartment in series with the four 20 watt vestibule lamps.

d. Vestibule

The vestibule illumination consists of 4-20 watt lamps, in

series. Two of these lamps are connected with an automatic interchanging device to lamps placed on outside of either door. These lamps light while the door is open.

e. Baggage compartment

The baggage compartment is illuminated with a single cluster of 5-20 watt lamps, one of which is interchangeable with the motorman's cab lamp.

In the case of no potential on the trolley the side lights can be connected to the storage battery for considerable time.

The signal lamps can be either connected to dynamotor current or to the storage battery.

Westinghouse metallic arc headlight to be used as shown on drawings.

8. General Equipment

A. Heating system

One Cooper pressed steel hot water heater with forced draft and circulation apparatus, is to be installed by car builder.

B. Signs

Signs to be mounted on the upper glass of the side doors.

C. Whistle

The whistle to be 2 1/2" in diameter and placed under the frame.

D. Hand brakes

One Peacock and Ackley vertical hand wheel brake to be installed at motorman's cab and one with rachet arrangement to be installed in vestibule.

E. Air brakes

Westinghouse automatic brake equipment schedule A.M.S. to be installed by car builders.

F. Sanders

One Keystone pneumatic sander to be installed at the front end.

G. Ventilators

Nine Garland ventilators to be installed on center line of roof as directed.

9. Trucks

Two cast steel frame M.C.B. type motor truck for high speed service of Commonwealth Steel Co., or equal design to be used on the car.

10. Electrical Equipment

1. Motors

Four 145 H.P., 600 volt direct current, interpole motors of Author's special design, insulated for 1200 volts, to be used on the car.

The two motors on each truck to be operated in series thus giving 1200 volt sets to conform with the trolley potential.

Specifications for the Motors

Motors must be able to develop sufficient tractive effort to give an acceleration to the fully loaded car weighing 50 tons of 1.6 miles per hour per second with a current not exceeding full load current.

Motors must have such characteristic as to assure reliable operation at high speeds.

Motors must be safely insulated for the highest potential on trolley line.

The ventilation of the motors must be forced by external blower. This blower must be fastened to the frame of the car and flexible tubing should be used to carry the air to the motors.

Motor suspension must have maximum flexibility.

The motor frame must be of the split form and every part of the motor must have easy access.

Motor Dimensions Constants and Characteristics

Voltage between terminals	600 V
Kilowatts output, full load	100
Efficiency at full load	90%
Amperes, full load	185
Kilowatts input, full load	111
Gear ratio	2.13

Armature

Diameter	15"
Length between core heads	18"
Thickness of core sheets (electric steel)	.0172"
No of ventilating ducts	4
Width of each duct	1/2"
Effective length of core	14.4"
Internal diameter of core	6 1/2"
Number of slots	37

Depth of slot	1.5"
Width of slot	.55"
Minimum width of tooth at root	.48"
Width of tooth at armature face	.726"
Total number of active conductors	370
Number of circuits	2
Area of conductors sq. in.	.0357
Section of conductors	.60"x.0595"
Section of conductor insulated	.63"x.0895"
Total insulation between conductor and core	.081"
Single air gap	.25"
Bore of field	15.5"

Pole piece

Pole piece length parallel to shaft	18"
Length of pole arc	8 1/4"

Magnet core

Length radially	3 1/4"
Length parallel to shaft	18"
Width	6"
Area of section sq. in.	108

Interpole core

Length radially	3 1/4"
Length parallel to shaft	12"
Width	3/4"
Area of section sq. in.	9
Minimum distance between interpoles and cores	1.875"

Area of field coil conductor sq. in	.135
Sectional area of yoke sq. in.	50
Length parallel to shaft	25"

Commutator

Diameter	12"
Length of segment over all	7 1/2"
No of segments	185

Commutator brushes

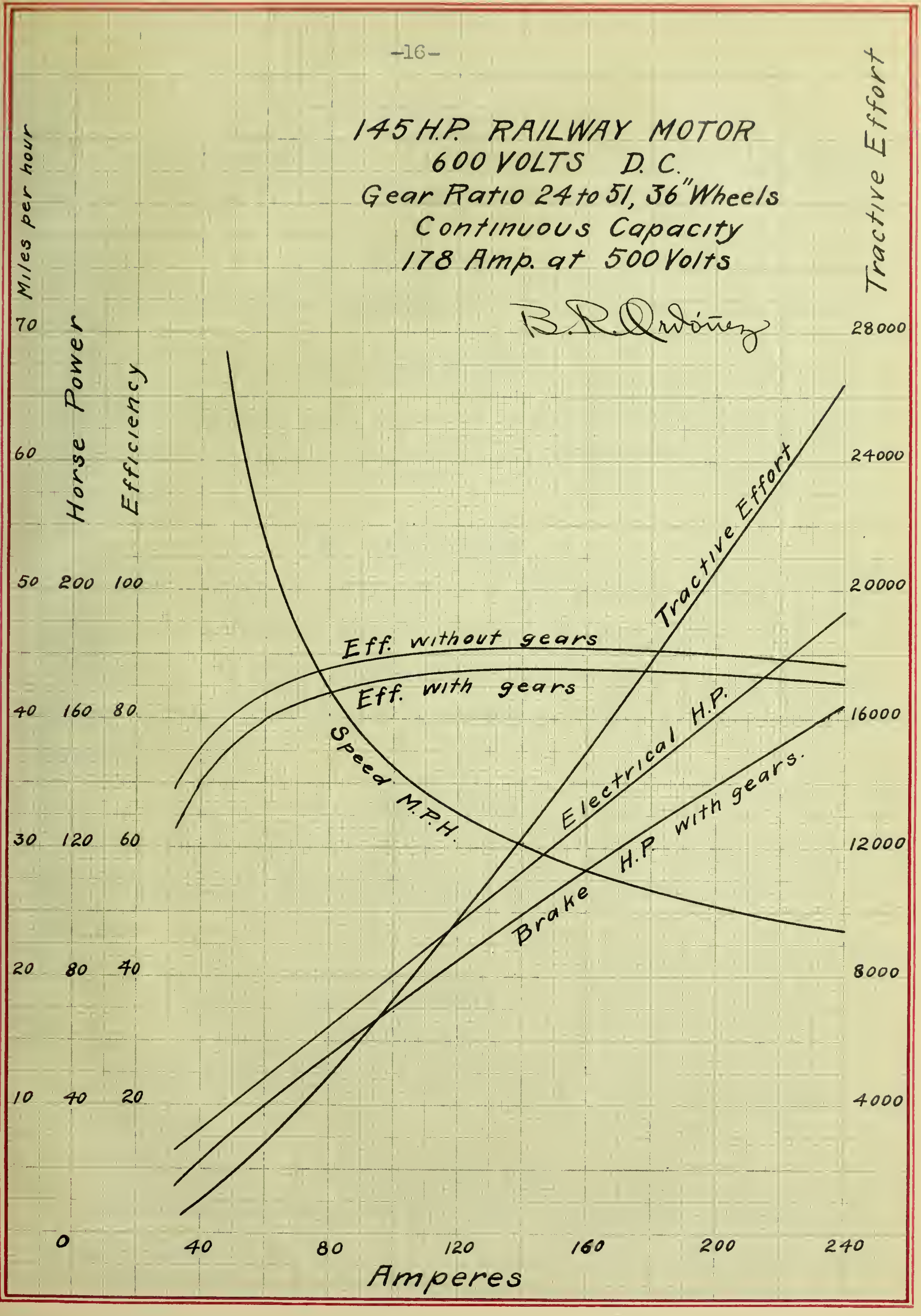
Number of sets	2
Number in one set	2
Length side by side	6"
Width (peripheral) of brushes	.5"
Armature voltage at no load	600
Average volts between commutator segments	13
Number of turns per field coil	53
Number of coils	4
Number of turns per interpole coil	19
Armature ampere conductors per pole	8500
Armature ampere conductors between poles	2500
Armature resistance	.0784
Total field resistance	.094
Total interpole resistance	.015
Total resistance not including brush resistance	.187

Motor rating with forced ventilation as used in the car

One hour rating - 600 volts, 200 amperes or 145 H.P.

Continuous rating - 500 volts, 178 amperes.

These last figures show conclusively that the motor car will operate very satisfactorily even with heavy trailing load without danger of overheating.



145 H.P. RAILWAY MOTOR
600 VOLTS D.C.
Gear Ratio 24 to 51, 36" Wheels
Continuous Capacity
178 Amp. at 500 Volts

B. R. Ordóñez

2. Controller

Westinghouse type A L, electro-pneumatic unit-switch control to be furnished by the purchaser and installed by the car builder.

3. Pantographs

Two Westinghouse pantographs to be installed by car builder.

4. Power Wiring

All power wiring is to be run in approved conduit furnished by builder. Controller cables to leave conduit in approved outlet boxes.

5. Light Wiring

Light wiring is to be put in by car builder. No. 12 copper wire is to be used and run in approved metal molding. All wiring is to be done in accordance with the rules of the National Electric Code. Car builder is to furnish light wire, conduit and fittings.

6. Switch Board

The switch board to be made of 1 1/2" Blue Vermont marble, with black marine finish, furnished and installed by the car builder.

11. Painting

A. Materials

All materials used for painting to be of the best class on the market.

White lead is to be absolutely pure.

Berry Brothers very best railway body varnish or equivalent is to be used.

All paint materials must be guaranteed by car builder.

B. Colors

The outside to be painted olive green. The inside is to be painted imitation mahogany throughout except the ceiling which is to be painted Nile green.

The vestibule is to be painted the same as the rest of the interior.

12. Delivery

The cars are to be delivered f.o.b. at car builder's works. The cars to be covered with canvas for shipment. All fragile parts to be safely secured to the inside of the car.

Directions for routing the shipment will be given later by purchaser.

III WEIGHT ESTIMATE

1. Bottom Frame

No. of pieces	Description	Total ft.	Wt. per ft. lb.	Total Weight lb.
2	Interior center sill, 8" channel	139'	16.25	2096
2	Exterior " " 8" "	125'	16.25	2034
2	Side sills, 8" channel	142'-8"	11.25	1606
4	Main bolster plates #000	36'	19.5	702
2	" " 13" special channels	20'	32	640
4 sets	Intersill reinforcing plates #4	40'	7.63	305
4	Main bolster reinforcing 12" channel	4'	20.5	102
4	" " " 4" "	4'	5.25	22
20	Body bolster plates #1	180	3.9	700
10 sets	" " intersill plates #4	100	7.63	763
1	Front end plate #1	20	11.8	236
1	Rear end plate #1	12	11.8	141
2	Anticlimbers	12'-6"	10.28	128
2	Stairs frame channels 5"	18'	6.5	117
4	" side plates #5	20	7.42	148
6	Steps #8 plate	25.3	5.24	132
2	Truss rod 1 1/4" round	86	4.17	358
4	" " end supports	3'-4"	10.2	34
4	" " queen posts			286
2	Drawbars, couplers, etc.			1000
1	Pilot			200
	Rivets and small iron			300
	Total bottom frame			12,050

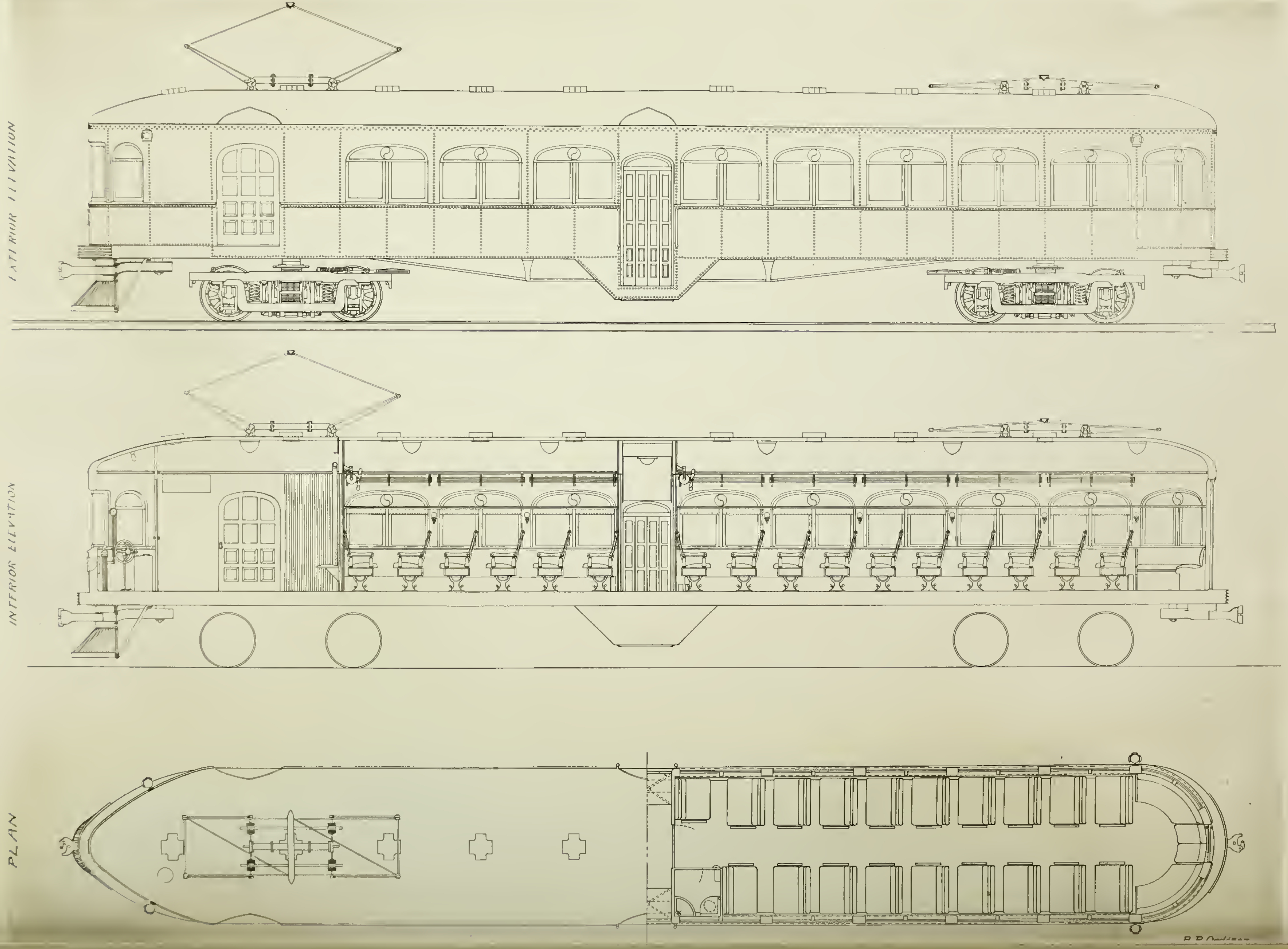
No. of pieces	Description	Total ft.	Wt. per ft. lb.	Total Weight lb.
	2. Sides			
18	Pressed steel window shapes #8	258	5.24	1480
	" " shapes for doors, etc. #8	147	5.24	770
18	Pier post shapes #10	273	4.15	1125
18	Intermediate window post shapes #10	85	4.15	352
1	Belt rail	128	5.1	653
2	Deck rails 4" x 4" angle	143	8.2	1170
	Exterior side sheathing #12	457	3.29	1500
	Interior " " #14	440	2.61	1140
	Door framings 4" channel	74	5.25	388
	" " 2" angle	97	2.5	242
	Miscellaneous			300
	Total sides			9120
	3. Vestibule and closets			
	Bulkhead framings 2" special channel shape #8	183	1.74	319
	Bulkhead sheathing #14	195	2.61	510
	Miscellaneous			81
	Total vestibule and closets			910
	4. Bulkheads			
	Framing 2" special channel shape #8	90	1.74	157
	Bulkhead sheathing #14	100	2.61	261
	Miscellaneous			42
	Total bulkheads			460

No. of pieces	Description	Total ft.	Wt. per ft. lb.	Total Weight lb.
	5. Roof			
25	Car lines pressed steel shapes #5	210	4.32	907
	Roof sheathing #14	670	2.61	1750
	Ceiling " #16	656	2.07	1350
	Agasote layer 1/4"	670	0.5	335
	Roof canvas	670	0.4	268
	Miscellaneous			300
	Total roof			4910
	6. Floor			
	Steel sheathing #8	232	5.24	1210
	Non-combustible flooring 3/8"	232	1.00	232
	Surfacer	232	.6	139
	Miscellaneous			49
	Total floor			1630
	7. Windows			
18	Top window sashes	180	1.74	313
18	Top window glasses A.A.- D.S.	45	1.56	70
36	Side " sashes	360	1.74	626
36	Side window glasses A.A.-D.S.	170	1.56	265
3	Motorman's cab window sashes	32	1.74	55
3	" " " glasses A.A.-D.S.	20	1.56	31
	Window fixtures			300
	Miscellaneous			40
	Total windows			1700

No. of pieces	Description	Total ft.	Wt. per. ft. lb.	Total Weight lb.
	8. Doors			
	Side doors framing #12	80	2.29	253
	" " glasses A.A.-D.S.	17	156	25
	Interior and end doors framing #12	120	3.29	394
	Interior and end door glasses A.A.-D.S.	18	1.56	28
	Baggage door framing #12	52	3.29	170
	" " glasses A.A.-D.S.	14	1.56	22
	Door fixtures			288
				1180
	9. Miscellaneous			
	Seats			3400
	Bag racks			320
	Ventilators			150
	Toilet rooms equipment			300
	Electric fans			80
	Paint			300
	Hot water equipment			2000
	Miscellaneous			250
	Total miscellaneous			6800

IV. SUMMARY OF WEIGHTS

	Total Weight lb.
1 - Bottom Frame	12050
2 - Sides	9120
3 - Vestibule and Closets	910
4 - Bulkheads	460
5 - Roof	4910
6 - Floor	1630
7 - Windows	1700
8 - Doors	1180
9 - Miscellaneous	6800
Total Body	38760
Body weight per ft. of over all length	596
" " " seat	538
" " " sq. ft. of floor	167
Total Body	38760
Air brake equipment	2500
Electric lighting equipment	200
Controller equipment	3000
Trucks	20000
Motors	20000
Pantographs	400
Motor ventilation equipment	140
Total weight of car ready for passengers	85600 lb.


EXTERIOR ELEVATION
INTERIOR ELEVATION
PLAN

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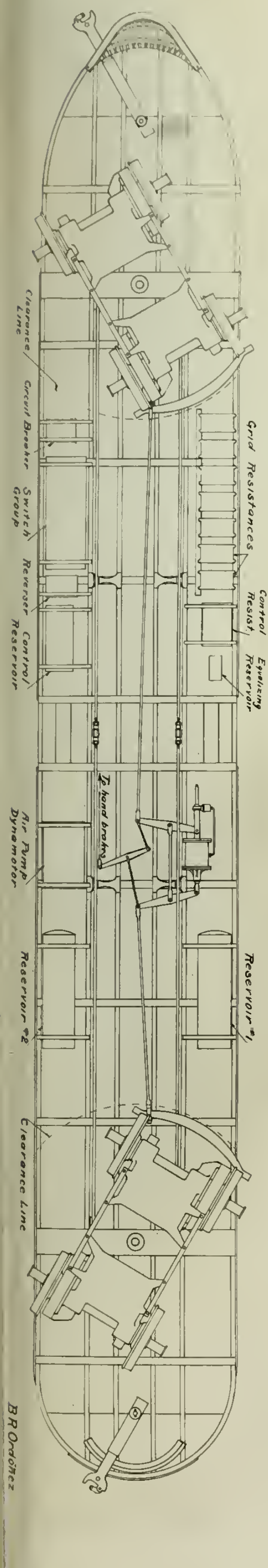
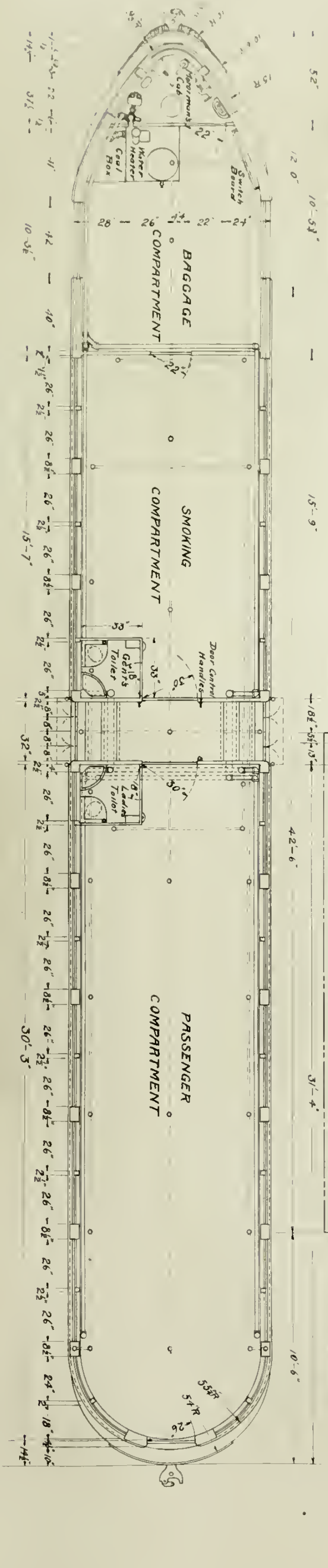
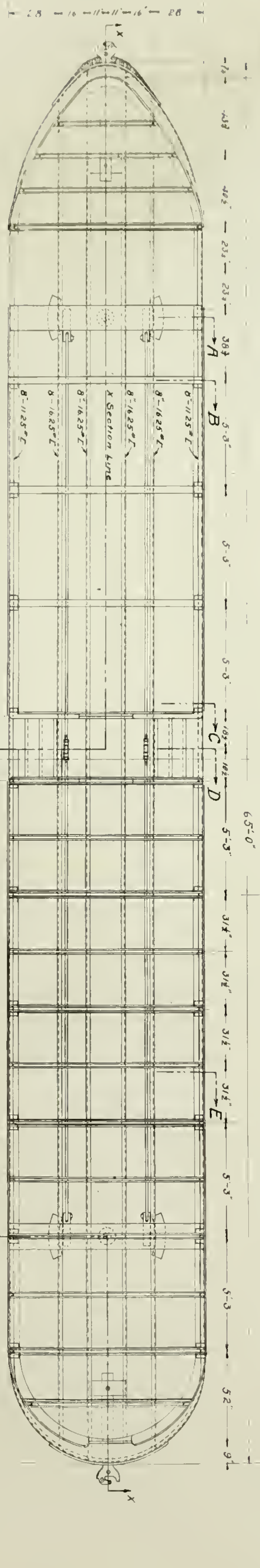
MOTOR CONTROL & BRAKE APPARATUS ARRANGEMENT BOTTOM VIEW



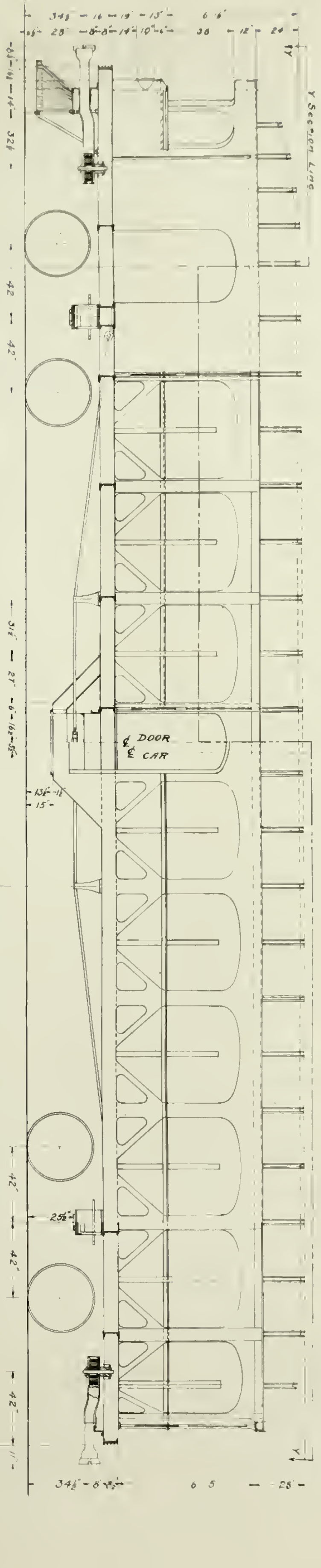
LIGHTING HEATING & VENTILATING SYSTEMS

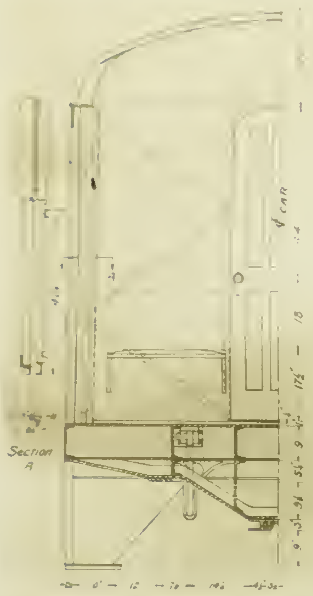


FRAME PLAN SECTION Y

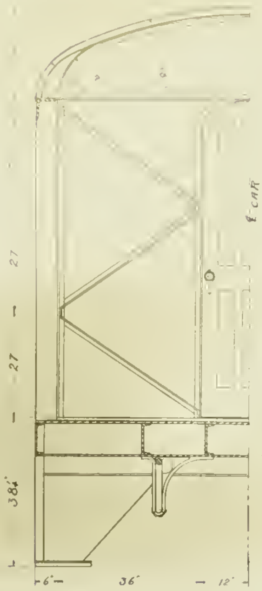


FRAME ELEVATION SECTION X





SECTION A



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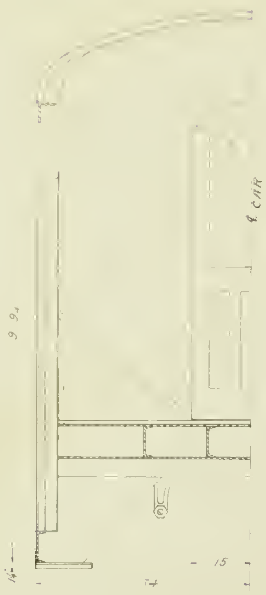

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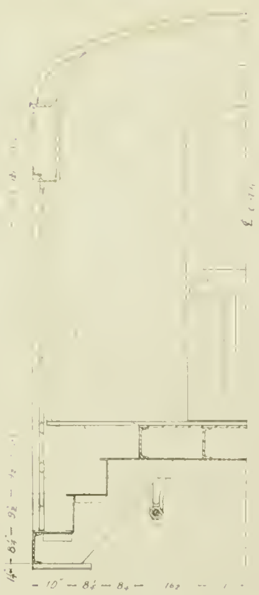

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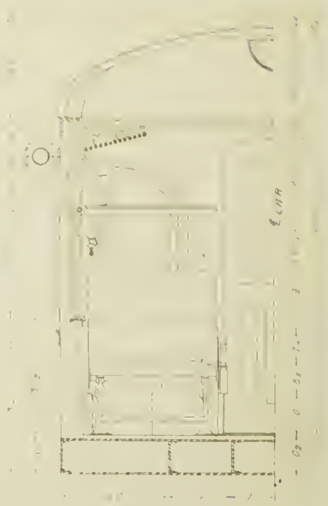
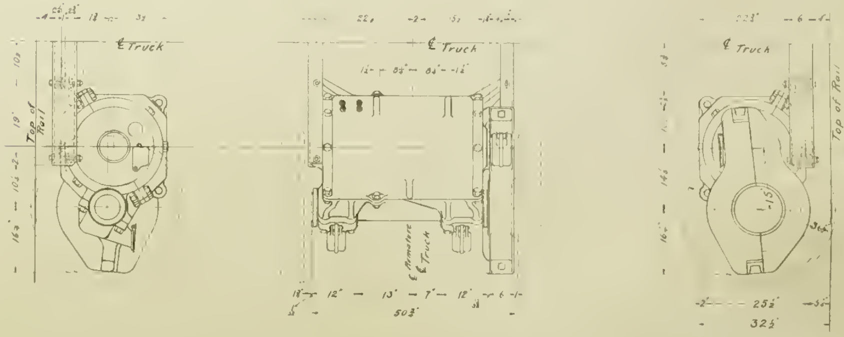
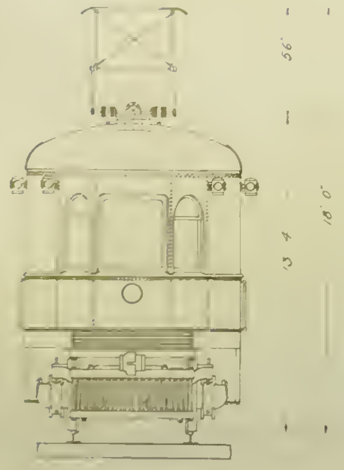
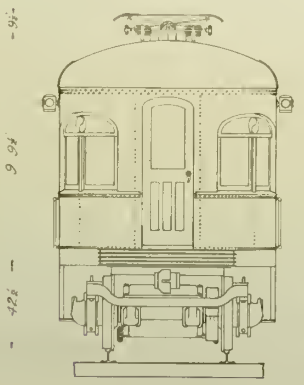


SECTION E

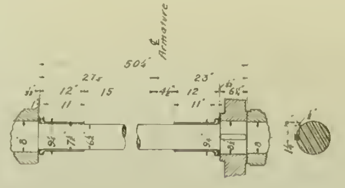




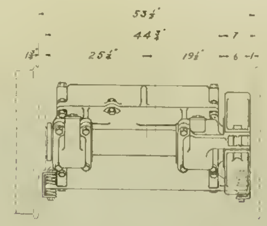
FRONT ELEVATION



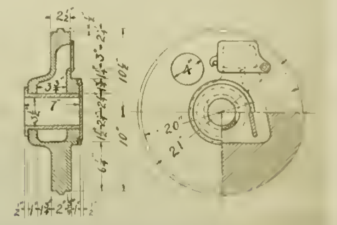
REAR ELEVATION



AXLE DETAILS



MOTOR VIEWS



MOTOR BEARING PLATES

BROrdóñez

UNIVERSITY OF ILLINOIS-URBANA
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